Journal of Tropical Crop Science Vol. 12 No. 3, October 2025
www.j-tropical-crops.com

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

Improvement of Soil Properties through Farmyard Manure and Lime for Barley Productivity in Acidic Hot Spot Areas of Ethiopia

Zelalem Addis*, Tadele Amare, Betewlegn Keribih, Desaleign Getaneh, Zimie Ambaw, Abrham Awoke, Abere Tenaegn

Adet Agricultural Research Center P.O.BOX 08, Bahir Dar, Ethiopia

*Corresponding author; email: zelalemaddis660@gmail.com

Abstract

The experiment was conducted to enhance barley productivity and improve soil properties in acid hotspots areas by applying farmyard manure and varying lime rates in the northwestern Amhara region, Ethiopia. The experiment comprised the combination of three levels of farmyard manure (0, 2, and 4 $t.ha^{-1}$) and four levels of lime (0, 25, 50, and 100%) with one plot containing 92% N from urea and 69% P_2O_5 from TSP which was laid out in randomized complete block design with three replications. Data on soil physico-chemical properties and yield components of barley were collected and subjected to ANOVA. The individual application of farmyard manure and lime had a significant impact on the yield components of barley. Similarly, soil properties changed slightly under the treatments compared to the soil before planting. Sole application of 4 $t.ha^{-1}$ farmyard manure and 100% lime (8.8 $t.ha^{-1}$) gives the highest grain and above-ground biomass yield (1.7 and 3.5 $t.ha^{-1}$) and (1.6 and 3.1 $t.ha^{-1}$), respectively, than the control and the pilot treatments. Similarly, the application of sole 4 $t.ha^{-1}$ scored the highest plant height (72.9 cm) compared to the control and pilot treatments. To achieve the highest net benefit within a short period, applying 4 $t.ha^{-1}$ and 25% (2.2 $t.ha^{-1}$) can be preferable for yield improvement in the study area and similar agro-ecological environments.

Keywords: animal dung, crop productivity, organic fertilizer, soil health

Introduction

Soil acidity has been recognized as a significant global issue, adversely affecting crop production, either directly or indirectly, particularly in temperate and tropical regions worldwide (Brady and Weil, 2002). It covers about 30% or 3,950 million ha of land area. It occurs mainly in two global belts: the northern belt (cold and temperate climate) dominated by Spodosols, Alfisols, Inceptisols, and Histosols, and the southern tropical belt consisting largely of Ultisols and Oxisols (Sumner and Noble, 2003). Acid soils in Ethiopia are widely distributed in highlands under varying climatic and environmental conditions. It covers nearly 40.9% of the area under cultivation (Panda, 2022). From this, 27.7% is moderately acidic (pH 4.5–5.5) and 13.2% is strongly acidic (pH <4.5) (Taye, 2007). The problem is more prevalent in areas with high rainfall, which enables the leaching of exchangeable bases from the soil surface (Holden et al., 2024). Soil acidification is one of the major causes of soil degradation, originating from various sources, including the addition of acid-forming fertilizers, intensive cultivation, precipitation, and heavy irrigation, which also contribute to the development of acidity in these soils. Hence, these soils are poor in basic cations. Poor growth of crops on these soils is attributed to the presence of toxic amounts of iron (Fe), aluminum (Al), and manganese (Mn), as well as deficiency of phosphorus (P) and molybdenum (Mo), and reduced activity of soil microorganisms (Dhananjaya and Ananthanarayana, 2020). This leads to a decrease in the pH value, which is caused by an increase in exchangeable acidity, and consequently results in a decrease in crop yield. The productivity losses in soil pH ranges of 5.5–6.5, 4.5–5.5, and less than 4.5 are up to 10%, 10–25%, and more than 50%, respectively (Jehangir et al., 2021).

In the case of the Amhara region, about 24% of the cultivated land is affected by acidity (ANRIO, 2023). The problem is known to have an adverse effect on crop growth, both directly and indirectly, through its impact on nutrient availability. The problem is particularly acute in Machakel and Guagusa Shikudad woredas, where most of the soils are predominantly acidic in nature, with an exchangeable acidity range

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

of 3.33 to 5.60. That forced most farmers to grow acid-tolerant crops at the expense of economically important crops or to allocate their cultivated lands to eucalyptus, *Acacia decurrens* plantations, and Engdo cultivation for many years.

Barley is a cool-season crop adapted to high-altitude regions. It is grown in a wide range of agroclimatic zones between 2,200–3,000 m above sea level (Getnet, 2023). The area allocated to barley reached about 1 million hectares in 2015/2016 (CSA, 2023). It is one of the most important crops for food, feed, and income generation for many smallholder farmers in Ethiopia's highlands (Mulatu and Grando, 2011). However, the productivity of barley in production fields has remained very low, at approximately 1.3 $t.ha^{-1}$, compared to the world average of 2.4 $t.ha^{-1}$ (CSA, 2021). This may be due to the soil being out of production or non-responsiveness related to the severe depletion of soil organic matter, which is particularly sensitive to acidity in barley compared to other crops, such as wheat. As a result, the yield was barely below its biological yield potential. Based on this, we suggest that to produce barley, it is first necessary to recover the non-responsive soil through the addition of organic matter, which is a key component of soil.

The treatments were implemented in a factorial design, combining different rates of farmyard manure and lime, to enhance barley yield and improve soil properties. Since the productivity of infertile acidic soils can be enhanced through the integrated use of soil ameliorants and fertilizers. Liming of acid soils supplemented with organic fertilizers increases soil pH and the availability of P, Mo, and N nutrients, while reducing exchangeable acidity (Tadesse, 2024). Similarly, the application of manure on acidic soils reduces Al^{3+} toxicity and increases the nutrient content of the soils (Tuneb et al., 2023). Since the application of farmyard manure is not a complete substitute for lime as an alternative ameliorant (Kebede and Lele, 2022), it is important to study and quantify the appropriate rates of lime and farmyard manure for barley production in acidic hotspot areas. This study was conducted to determine the economic and biological optimum levels of lime and farmyard manure for barley production, as well as to improve soil properties in highly acidic areas of the Western Amhara region.

Materials and Methods

The experiment was conducted on farmers' fields in the Guagusa Shikudad and Machakel districts for two consecutive years, spanning the 2020/2021 and 2021/2022 cropping seasons, at Guagusa Shinkurta and Debrekelemo Kebles in Awi and East Gojjam zones of the northwestern Amhara Region, Ethiopia. Guagusa Shikudad district is located 129 km from Bahirdar. Geographically, the area lies at 100°36'22'' N and 360°25'15'' E (Figure 1) with a mean altitude of 2,204 m above sea level. It receives a mean

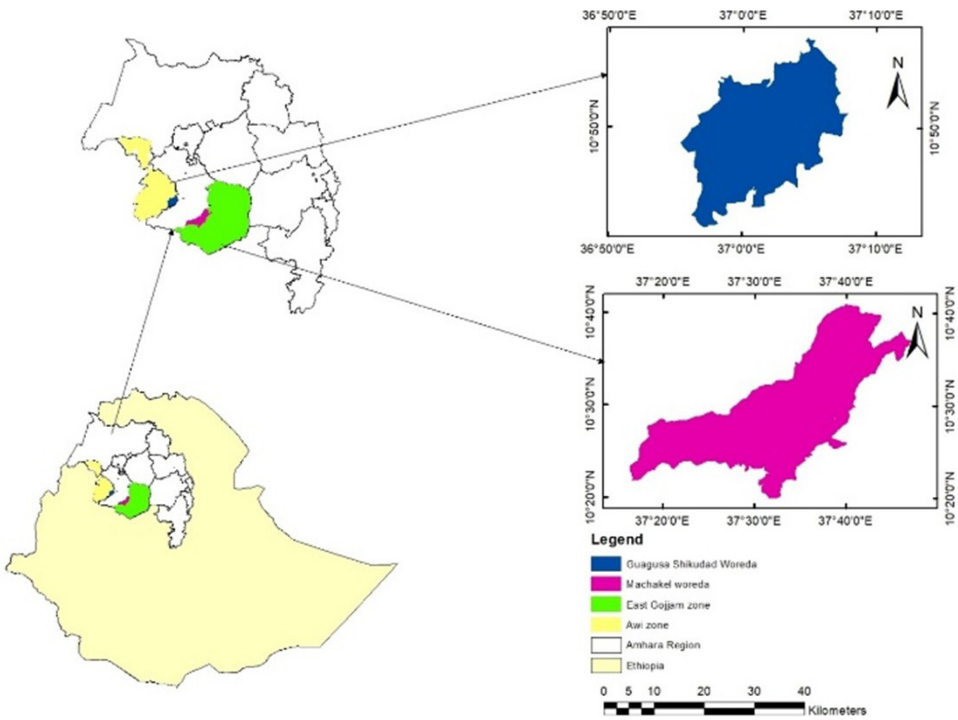


Figure1. The geographical location of the study areas

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

annual rainfall of 1,356 mm, with mean minimum and maximum temperatures of 10°C and 28°C, respectively, Bureau of Agriculture (BoA). According to the district Bureau of Agriculture, the major land use comprises cultivated land (62.6%), forest and bushes (14.6%), grazing land (22.2%), and other uses (0.6%). Major crops grown in the study area include barley, wheat, potatoes, and faba beans, which account for the lion's share. The major soil types include Andisols, Nitosols, and Cambisols. Generally, the soil types of the study area are characterized by shallow to very deep profiles, with moderate to deep in-depth profiles, and sandy clay to clay textures (Alemayehu, 2015). Machakel district is also located 235 km away from Bahirdar. Geographically, the area lies at 10˚51'40'' latitude and $37^0$61'66'' longitude E (Figure 1) with a mean altitude of 2600 m above sea level. It receives a mean annual rainfall of 1,350 mm with a mean annual temperature of 25°C, respectively (BoA). According to the district Bureau of Agriculture (BoA), the major land use comprises cultivated land (52.3%) and other uses (47.7%). Major crops grown in the study area include wheat, potato, barley, teff, triticale, and Engedo. The major soil types include andisols and nitosols.

Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications, which had thirteen treatments. From this, the twelve treatments were obtained from the combination of three levels of farmyard manure (0, 2, and 4 $t.ha^{-1}$) and four levels of lime 0%, 25%, 50%, 100% in addition to one pilot treatment (containing 92% N from urea and 69% P_2O_5 from TSP). The experiment was conducted under rain-fed conditions, and the food barley variety HB-1307 was used as the test crop. The total area of each plot was 4 m x 3 m (12 m^2), with a 1 m space between plots and blocks. Rows were spaced 0.2 m. Recommended fertilizer was applied during the growing period in all plots except the pilot plots. Soil samples were collected at depths of 0-20 cm before planting. Simultaneously, the core samples for each soil sample were collected for the determination of the bulk density of the soil, which is important for the calculation of the amount of lime using the following formula:

$$\text{Lime } (CaCO_3)\ (kg.ha^{-1}) = \frac{\text{Net acidity } (cmol.kg.ha^{-1}) \times 0.2\ m \times 10{,}000\ m^2 \times BD \times 1000}{2000} \times 1.5$$

Notes: BD is bulk density in cubic megameter; 1.5 is the safety factor.

The soil samples were air-dried, ground, and sieved according to standard procedures. For analysis of soil chemical properties, including exchangeable acidity, in the Adet Agricultural Research Center Soil Laboratory. Bulk density was determined by the core sampling method. After planting, major chemical properties of soil, such as OC, pH, CEC, total N, and AvP (available P), were analyzed following the compiled laboratory manual of Sahlemedhin and Taye (2000). Soil pH was measured in water at a ratio of 1:2.5. The soil OC content was determined following the wet digestion method as outlined by Walkley and Black, which involves the digestion of the OC in the soil samples with potassium dichromate ($K_2Cr_2O_7$) in a sulphuric acid solution. Available P was determined by the Olsen extraction method. The total N content in the soil sample was determined following the Kjeldahl method. CEC was determined by extracting soil samples with ammonium acetate (1N NH_4OAc), followed by repeated washing with ethanol (96%) to remove the excess ammonium ions in the soil solution. Percolating the NH_4^+ saturated soil with sodium chloride would displace the ammonium ions absorbed in the soil, and the ammonium liberated from the distillation was titrated using 0.1N NaOH. The agronomic parameters include plant height, spike length, grain yield, and biomass yield. All data were subjected to analysis of variance (ANOVA) using the SAS software program, version 9.4 (SAS Institute, 2002). A Least Significant Difference (LSD) test at the 0.05 probability level was employed to separate treatment means where significant differences existed (Gomez and Gomez, 1984). Economic analysis was conducted using partial budget analysis and the marginal rate of return (MRR), which are tools used to evaluate changes in farming practices that affect only part of the farm rather than the entire system. These methods also serve as planning tools to estimate profit changes within a farm (CIMMYT, 1988). The analysis was computed by adjusting the yield downward by 10% and multiplying it by the local field price of barley, which was 23 Ethiopian $Birr.kg^{-1}$. The cost of farmyard manure and lime was 0.2 Birr and 80 Birr per unit, respectively. Dominance analysis was performed by arranging treatments in increasing order of cost; any treatment with a net benefit less than or equal to that of a treatment with a lower cost was considered dominated (CIMMYT, 1988).

Results and Discussion

Soil Chemical Properties Before and After the Harvest and Planting

Laboratory results of the soil before and after planting across districts from each experimental site are described in Tables 1 and 2. Before planting, soil results from different experimental sites indicated that each site was acidic with a high exchangeable acidity,

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

which is an unsuitable range for barley production (Tadese, 1991). Similarly, the total N, available P, OC, and CEC of the soil Guagusa shikudadd, Machakel 2020/2021 and Machakel 2020/2022 before planting were (0.188%, 0.11%, and 0.131%), (14.403, 5.776, and 4.560 ppm), (2.734%, 1.509%, and 1.450%), (29.64, 24.70, and 23.30 cmol(+).kg^{-1}), respectively (Table 1). The total N content of the soil was within the range of low to medium, according to Tadese (1991), who classified the total N range as follows: <0.1%, 0.1-0.15%, 0.15-0.25%, and >0.25%. Based on Olsen et al. (1954), classified available P content in the range <5 as very low, 5-15 as low, 15-25 as medium, and >25 mg.kg^{-1} as high. Hence, the available phosphorus (P) in the soil before planting across sites falls within the very low to low range. Similarly, according to Landon (1991), the soil OC content ranges of 1-2, 2-4, and 4-6% are rated as low, medium, and high, respectively on the other hand cation exchange capacity (CEC) ranges of 5-15, 15-25 and 25-40 cmol(+).kg^{-1} are rated as low, medium and high. Based on these ratings, the OC and CEC, before planting the experimental fields of each site, were in the low to medium and medium to high ranges, respectively. In general, the nutrient status of the study sites, particularly at Machakel, was found to be poor in terms of the availability of major plant nutrients. However, Guagusa Shikudad exhibited a relatively favorable cation exchange capacity (CEC). On the other hand, after planting, all soil chemical properties, including pH, showed changes in value across experimental sites, except for some variability in Guagusa Shikudad due to the application of lime with farmyard manure compared to the control and pilot treatments (Table 2) and Figure 2. Numerically, the highest value of selected soil chemical properties displayed in Table two was scored by the combined application of lime and farmyard manure across sites as compared to the control. The increase in these soil properties may be related to the release of basic cations in the soil solution, which substitute for acid cations and lead to neutralization in the rhizosphere, beyond the supplemented nutrients provided by the plant. These results agreed with the investigation of Fekadu et al. (2022) who reported that the application of compost, lime, and farmyard manure with inorganic

Table 1. Soil chemical properties before planting across experimental sites

Bulk density (g.cm^{-3})	Total N (%)	Organic carbon (%)	Cation exchange capacity	Average P (ppm)	Exchangeable acidity	Lime requirement per site (kg)
Guagusa Shikudad (2020/2021)						
1.3	0.188	2.734	29.64	14.403	3.33	6.5
Machakel (2020/2021)						
1.2	0.115	1.509	24.70	5.776	4.81	8.6
Machakel (2021/2022)						
1.4	0.131	1.450	23.30	4.560	5.60	11.3

Table 2. Soil chemical properties after planting across experimental sites

Treatments	Guagusa Shikudad (2020/2021)					Machakel (2020/2021)					Machakel (2021/2022)				
	pH	TN%	OC%	CEC (cmol-kg)	AvP (ppm)	pH	TN%	OC%	CEC (cmol-kg)	AvP (ppm)	pH	TN%	OC%	CEC	AvP (ppm)
0,0 (FY, LM)	5.25	0.07	3.13	31.9	16.01	5.19	0.22	2.52	23.18	9.231	5.04	0.18	1.65	26.94	11.76
0,25% (FY, LM)	5.32	0.11	3.1	34.46	18.14	5.4	0.21	2.17	24.48	12.17	5.33	0.19	1.33	25	11.32
0,50% (FY, LM)	5.45	0.2	3.02	33.18	13.89	5.71	0.19	1.98	30.16	17.94	4.96	0.17	1.31	25.26	12.01
0,100% (FY, LM)	5.48	0.16	2.75	34.5	15.33	6.34	0.22	2.26	29.24	16.32	5.52	0.17	1.36	28.32	10.19
2,0 (FY, LM)	5.2	0.13	3.37	34.96	17.58	5 .18	0.17	2.37	27.66	8.27	5.12	0.18	1.36	25.5	11.26
2,25% (FY, LM)	5.27	0.14	3.06	37.04	19.27	5.22	0.22	1.92	29.28	12.11	5.18	0.19	1.39	30.42	11.76
2,50% (FY, LM)	5.38	0.16	3.19	34.02	16.89	5.43	0.22	2.39	31.64	11.21	5.32	0.18	1.67	30.52	8.88
2,100% (FY, LM)	5.76	0.13	2.94	35.14	17.7	5.48	0.22	2.22	25.94	9.652	5.56	0.18	1.41	29.82	10.63
4,0 (FY, LM)	5.24	0.17	3.44	34.66	19.33	5.07	0.18	2.35	25.32	11.87	4.9	0.13	1.42	20.66	10.51
4,25% (FY, LM)	5.31	0.16	3.21	34.54	17.7	5.18	0.23	1.92	27.5	7.55	4.98	0.14	1.58	28.4	8.755
4,50% (FY, LM)	5.2	0.2	3.19	31.36	19.96	5.73	0.24	2.13	32.16	14.52	5.03	0.18	1.3	29.34	10.13
4,100% (FY, LM)	5.54	0.13	3.08	33.92	16.83	6.14	0.21	2.44	28.6	10.25	5.78	0.16	2.12	31.28	10.82
Pilot	5.08	0.13	3.1	38.4	17.64	5.15	0.22	2.28	28.36	10.91	5.15	0.19	1.07	26.36	9.881

Notes: FY =farmyard manure levels (0, 2, 4 t.ha^{-1}), LM=lime levels (0, 25, 50,100%) of the lime requirements in each site, pilot = (92N, 69P_2O_5), pH=concentration of hydrogen, TN=total nitrogen, OC=organic carbon, CEC=cation exchange capacity, AvP=available phosphorus.

Journal of Tropical Crop Science Vol. 12 No. 3, October 2025
www.j-tropical-crops.com

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

P has increased (make a change) the soil chemical properties as compared to control or non-treated plots at Lay Gaint District, Northwestern Highlands of Ethiopia.

Plant Height and Spike Length

The combined application of farmyard manure and lime did not significantly (P<0.05) affect plant height (PH) and spike length (SL) across years and sites (Table 3). However, the individual application of farmyard manure had a significantly greater

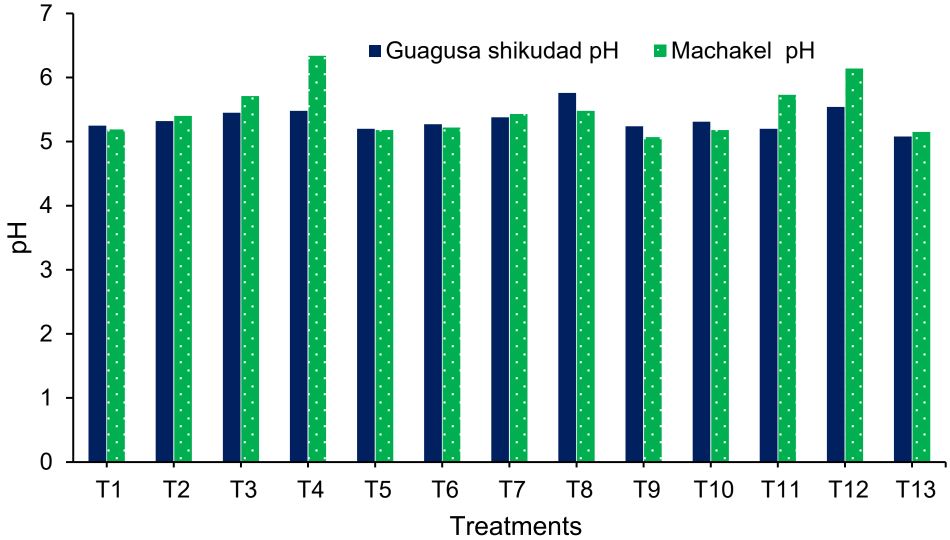


Figure 2. Effects of farmyard manure and lime on soil pH at harvest across the study area. T1 = 0 $t.ha^{-1}$ farmyard manure with 0% lime, T2 = 0 $t.ha^{-1}$ farmyard manure with 25% lime, T3 = 0 $t.ha^{-1}$ farmyard manure with 50% lime, T4 = 0 $t.ha^{-1}$ farmyard manure with 100% lime, T5 = 2 $t.ha^{-1}$ farmyard manure with 0% lime, T6 = 2 $t.ha^{-1}$ farmyard manure with 25% lime, T7 = 2 $t.ha^{-1}$ farmyard manure with 50% lime, T8 = 2 $t.ha^{-1}$ farmyard manure with 100% lime, T9 = 4 $t.ha^{-1}$ farmyard manure with 0% lime, T10 = 4 $t.ha^{-1}$ farmyard manure with 25% lime, T11 = 4 $t.ha^{-1}$ farmyard manure with 50% lime, T12 = 4 $t.ha^{-1}$ farmyard manure with 100% lime and T13 = pilot (contain 92% N and 69% P_2O_5).

Table 3. The main effects of lime and farmyard manure on plant height and spike length of Barley at Machakel and Guagusa Shikudad

Treatment	Guagusa Shikudad 2020/21		Machakel 2020/21		Machakel 2020/22		Combined over the years	
	PH (cm)	SL (cm)	PH (cm)	SL (cm)	PH (cm)	SL (cm)	PH (cm)	SL (cm)
0 $t.ha^{-1}$ farmyard manure	70.7^b	6.4	58.8^b	6.1	63.4^b	5.8	$63.1±1.3^b$	6.1
2 $t.ha^{-1}$ FY	79.9^a	6.6	60.0^b	5.9	67.1^{ab}	5.9	$69.0±1.6^a$	6.1
4 $t.ha^{-1}$ FY	83.0^a	6.8	63.5^a	6.0	72.1a	6.0	$72.9±1.5^a$	6.2
LSD	5.0	ns	3.1	ns	5.0	ns	4.5	ns
Farmyard manure	*	-	*	-	*	-	*	-
0% lime (0 $t.ha^{-1}$)	74.5	6.4	57.1^b	5.8	64.5	5.6	65.4	6.0
25% lime (2.2 $t.ha^{-1}$)	76.8	6.5	61.0^a	5.8	67.3	5.7	68.4	6.0
50% lime (4.4 $t.ha^{-1}$)	80.2	6.7	62.5^a	6.1	67.7	6.3	70.2	6.3
100% lime (8.8 $t.ha^{-1}$)	80.0	6.8	62.5^a	6.1	70.7	6.0	71.1	6.3
LSD	ns	ns	3.6	ns	ns	ns	ns	ns
Lime*Farmyard manure	ns	ns	ns	ns	ns	ns	ns	ns
CV%	7.7	12.5	6.1	9.0	8.7	12.6	13.8	12.1
Pilot (92N,69P_2O_5)	67.9	5.9	56.4	5.7	70	5.7	64.8	5.8

Notes: *= significantly different at P<0.05, ns= not significant. FY=farmyard manure, PH= plant height, SL=spike length.

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

influence on plant height than either lime alone or the combined treatment. The highest plant height (72.9 cm) was recorded with the application of 4 t.ha^{-1} of farmyard manure, compared to the control and pilot treatments, which measured 63.1 cm and 64.8 cm, respectively (Table 3). The increase in plant height in response to farmyard manure application may be attributed to improvements in soil properties, which enhance water absorption and nutrient uptake by the plant root system or rhizosphere. Moreover, farmyard manure can provide a balanced source of micro- and macronutrients, thereby increasing the availability of plant nutrients and enhancing microbial activity, which in turn promotes plant growth. These findings are consistent with those of Abera et al. (2018), who reported that the highest plant height of food barley was achieved through the application of 50% vermicompost combined with 50% conventional compost, compared to the control and the 50:50% conventional compost with NP. Similarly, a study by Hadis et al. (2018) showed that applying 4 t.ha^{-1} of vermicompost significantly increased barley height by 6.39 cm compared to the control.

Grain Yield and Above-Ground Biomass

The combined analysis results from both years across sites indicate that yield and the yield component of food barley were not significantly affected (P<0.05) by the combined effects of farmyard manure and lime application (Table 4). Instead, the application of farmyard manure had a significant impact on both grain yield and above-ground biomass, in addition to its integration with lime (Table 4 and Figure 3). Related to this, the numerically highest values of both grain yield (1.7 t.ha^{-1}) and above-ground biomass (3.5 t.ha^{-1}) were obtained by applying 4 t.ha^{-1} farmyard manure (FY) compared to the control and pilot treatments. This might be due to the positive main effect of farmyard manure on soil acidification amelioration or chelation of acid-forming cations, which helps make plant nutrients available in the plant root system or rhizosphere beyond their nutrient supplement as an organic fertilizer. Moreover, FY results in the release of organic acids that complex Al and Fe, thereby reducing P retention and enhancing P availability.

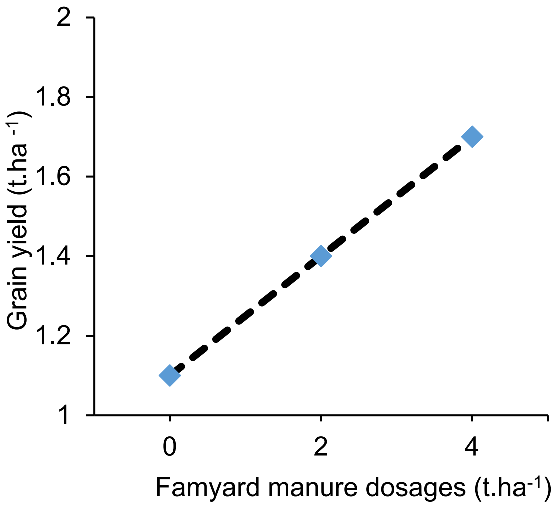
The result of the study aligns with the findings of Agegnehu et al. (2019), who found that applying 4 and 8 t.ha^{-1} FYM with 26 kg P.ha^{-1} on acid Nitisols in Holetta, Ethiopia, increased faba bean seed yield by 97% and 104%, respectively, compared to the control treatment. In the same way, the study conducted by Woldesenbet and Tana (2016) implied that an application of 5 t.ha^{-1} farmyard manure gives the highest (2,581 kg.ha^{-1}) grain yield of food barley as compared to control or untreated treatment. In addition, Hadis et al. (2018) indicated that the sole application of vermicompost at rates of 2, 4, and 6

Table 4. Main effects of lime and farmyard manure on grain yield and above-ground biomass of Barley at Machakel and Guagusa Shikudad

Treatments	Guagusa 2020/2021		Machakel 2020/2021		Machakel 2020/2022		Combined over the years	
	GY t.ha^{-1}	BY t.ha^{-1}	GY t.ha^{-1}	BY t.ha^{-1}	GY t.ha^{-1}	BY t.ha^{-1}	GY t.ha^{-1}	BY t.ha^{-1}
0 t.ha^{-1} farmyard manure	1.1^{b}	2.3^{c}	0.87^{b}	1.9^{b}	1.1^{b}	2.0^{b}	1.1±0.48^{c}	2.1±0.12^{c}
2 t.ha^{-1} farmyard manure	1.8^{a}	3.4^{b}	1.2^{a}	2.8^{a}	1.1^{b}	2.2^{b}	1.4±0.08^{b}	2.8±0.87^{b}
4 t.ha^{-1} farmyard manure	2.1^{a}	4.0^{a}	1.3^{a}	3.1^{a}	1.7^{a}	3.4^{a}	1.7±0.07^{a}	3.5±0.65^{a}
LSD	0.28	0.58	0.21	0.44	0.24	0.4	0.20	0.31
Farmyard manure	*	*	**	*	*	**	**	**
0% lime (0 t.ha^{-1})	1.5	3.0	0.82^{b}	1.8^{c}	1.1	2.2^{b}	1.2±0.09^{b}	2.3±0.18^{c}
25% lime (2.2 t.ha^{-1})	1.6	3.0	1.1^{a}	2.5^{b}	1.3	2.6^{ab}	1.4±0.09^{a}	2.7±0.18^{b}
50% lime (4.4 t.ha^{-1})	1.8	3.3	1.2^{a}	2.9^{b}	1.2	2.6^{ab}	1.4±0.08^{a}	2.9±0.15^{ab}
100% lime (8.8 t.ha^{-1})	1.8	3.6	1.3^{a}	3.1^{a}	1.5	2.9^{a}	1.6±0.09^{a}	3.1±0.18^{a}
LSD	NS	NS	0.24	0.5	NS	0.46	0.20	0.40
Lime*Farmyard manure	NS	NS	NS	NS	NS	NS	NS	NS
CV%	19.5	21.4	22.1	20.1	22.6	18.8	26.2	23.6
Lime	-	-	*	**	-	*	**	**
Pilot (92N,69P_2O_5)	1.1	2.2	0.67	1.5	1.1	2.2	1.0	2.1

Notes: *= significantly different at P<0.05, **= significantly different at P<0.01, ns= not significant. GY=grain yield, BY= above-ground biomass, LDS= Least significant difference.

Journal of Tropical Crop Science Vol. 12 No. 3, October 2025
www.j-tropical-crops.com
Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524



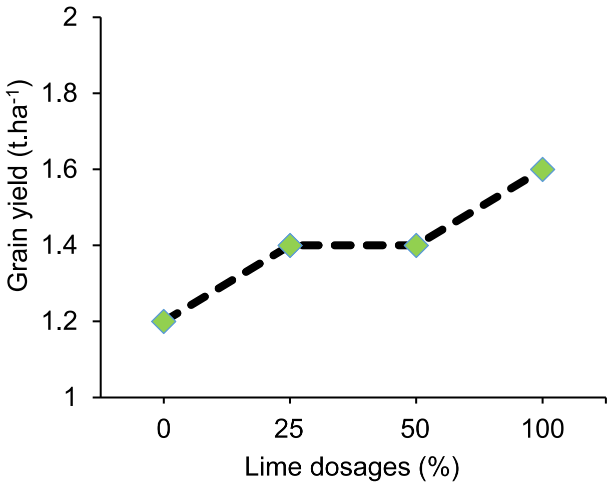


Figure 3. The effects of farmyard manure (A) and lime (B) over the years on grain yield

Table 5. Partial budget and marginal analysis of Barley as affected by the main effect of farmyard manure and lime application in acid hot spot areas of northwestern Amhara Region

Treatments	Actual grain yield (t.ha^{-1})	Actual grain yield (t.ha^{-1})	Total variable cost (Birr ha^{-1})	Net benefits (Birr ha^{-1})	Marginal rate of return (%)
Farmyard manures (t.ha^{-1})					
0	1.1	0.11	0	19,800	0
2	1.4	0.14	1030	24,170	424.3
4	1.7	0.17	2060	28,540	424.3
Lime (t.ha^{-1})					
0 (0%)	1.2	0.12	0	21,600	0
2.2 (25%)	1.4	0.14	2,320	22,880	55.2
4.4 (50%)	1.4	0.14	4,640	20,560	D
8.8 (100%)	1.6	0.16	9,280	19,520	D

t.ha^{-1} can increase grain yield and above-ground biomass by 11%, 17%, and 26%, respectively, compared to the control or unfertilized treatment. Similarly, the sole application of lime beyond its combination with farmyard manure significantly affected both grain yield and above-ground biomass of food barley at ($p<0.05$) in Table 4. The highest values of both gain yield (1.6 t.ha^{-1}) and above-ground biomass (3.1 t.ha^{-1}) were observed at 100% lime application (8.8 t.ha^{-1}), compared to the control and the pilot treatment (Table 4 and Figure 3B). This may be related to the amelioration of soil acidity as the pH increases, which reduces the active forms of Al and Fe, while enhancing the availability of P, Ca, and Mg, and improving the physical environment of the soil in the plant root system. The study concurred with the findings of Rajneesh (2020), who reported that supplying lime for four decades in the wheat-maize cropping system consistently increased the grain yield of wheat compared to the control and N alone treatments. Similarly, the result aligns with Demil et al. (2020), who observed that applying 25% lime yields a 90.23% advantage over previously wheat production years in highly acidic areas of the northwestern Amhara region.

Partial Budget Analysis

Net benefits were considered by the current fertilizer (farmyard manure) cost of 0.2 Birr.kg^{-1}, the cost of lime 0.8 Birr.kg^{-1}, the field price of Barley was 20 Birr. kg^{-1}, and the cost of labor per man day in the area was 70 Birr. The marginal rate of return of 100% was used to determine the acceptability of treatments. This economic analysis indicated that most farmyard treatments yielded the highest net benefit over the control (Table 5). The addition of both 2 and 4 t.ha^{-1} (farmyard manure) benefit with a marginal rate

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

of return of 424.3% respectively. This indicates that for every 1 Birr invested in farmland at 2 and 4 $t.ha^{-1}$ FY, farmers can obtain an additional 4.24 Birr (CIMMYT, 1988). Similarly, the economic analysis of lime also indicated that the addition of 25% lime (2.2 $t.ha^{-1}$) numerically yields the highest net benefit (21,600), with a marginal rate of return of 55.2% compared to the control and other dominated treatments. This also implies that for every 1 Birr invested in 2.2 $t.ha^{-1}$ (25% lime) in farmland, it can enable farmers to obtain an additional 0.552 Birr (21). All treatments for farmyard manure and lime sole application could be acceptable for barley producers in the study area, except the dominated ones. So that by considering the residual importance of farmyard manure for soil and crop production, application of 4 $t.ha^{-1}$ FY with 25% lime (2.2 $t.ha^{-1}$) should be recommended in these acid hot spot areas for barley production.

Conclusions

The application of farmyard manure and lime significantly improved both barley productivity and soil properties in these non-responsive soils. Therefore, farmers may benefit from applying 4 $t.ha^{-1}$ of farmyard manure and 25% of the recommended lime rate (equivalent to 2.2 $t.ha^{-1}$), depending on their resource availability. However, to establish barley as a viable alternative crop within the farming systems of non-responsive, acidic hotspot areas such as Debrekelemo and Guagusa Shikudad, a holistic approach to soil management is required. This includes integrated soil fertility management, soil and water conservation measures, as well as forestry and agroforestry interventions, to restore and sustain soil functionality for long-term agricultural productivity.

Acknowledgment

The author gratefully acknowledges the support provided by the Adet Agricultural Research Center, particularly in terms of administration and funding.

References

[ANRIO] Amhara National Regional State's Investment Office. (2023). Potential survey, identification of opportunities, and preparation of project profiles and feasibility studies, part one, potential assessment. Unpublished soil survey study report by Development Studies Association (DSA) and Shawel Consult International (SCI).

Abera, T., Tufa, T., Midega, T., Kumbi, H., and Tola, B. (2018). Effect of integrated inorganic and organic fertilizers on yield and yield components of barley in Liben Jaw District. *International Journal of Agronom*y **9**,1-7. https://doi.org/10.1155/2018/2973286.

Agegnehu, G., Bekele, T., and Tesfaye, A. (2019). Phosphorus fertilizer and farmyard manure effects on the growth and yield of faba bean and some soil chemical properties in an acidic nitisol of the Central Highlands of Ethiopia. *Ethiopian Journal of Natural Resources* **7**, 23-39.

Alemayehu, B. (2015). "GIS and remote sensing based land use/land cover change detection and prediction in Fagita Lekoma Woreda, Awi Zone, North Western Ethiopia". Addis Ababa, Ethiopia.

Brady, N.C., and Weil, R.R. (2002). "The Nature and Properties of Soils." 13th ed. New Jersey, Prentice- Hall Inc. USA.

[CIMMYT] International Maize and Wheat Improvement Center. (1988). "From Agronomic Data to Farmer's Recommendation: An Economic Training Manual." Revised Ed. Mexico.

[CSA] Central Statistics Agency. (2023). "Agricultural sampling survey (2023/24). Report on the area and production of major crops in the Meher season". Addis Ababa, Ethiopia.

[CSA]. Central Statistical Agency. (2021). "Agricultural sample survey: Report on area under cultivation, yield, and production of the major crops". CSA, Addis Ababa, Ethiopia.

Demil, A., Amare, T., Awoke, Y., Derebe, A., and Adera, T. (2020). Bridging the yield gaps of bread wheat at a scale through an innovative method of lime application in the acidic soils of Northwestern Ethiopia. *Journal Cogent Food and Agriculture* **6**, 46-58. DOI: https://doi.org/10.1080/23311932.2020.1803578.

Dhananjaya, B.C., and Ananthanarayana, R. (2020). Forms of acidity in some acidic inceptisols of southern Karnataka. *Agropedology* **20**,49–52.

Fekadu, E., Kibret, K., Melese, A., Bedadi, B., Yitaferu, B., and Mishra, B.B. (2022). Effects of lime, mineral P, farmyard manure, and compost on selected chemical properties of acid soils in

Received 25/11/2024; Revised 8/7/2025; Accepted 22/08/2025
https://doi.org/10.29244/jtcs.12.03.516-524

Lay Gayint District, Northwestern highlands of Ethiopia. *International Journal of Plant and Soil Science* **19**, 1-16. DOI: https://doi.org/10.9734/IJPSS/2017/35915.

Holden, F.J., Davies, K., Bird, M.I., Hume, R., Green, H., Beerling, D.J., and Nelson, P.N. (2024). In-field carbon dioxide removal via weathering of crushed basalt applied to acidic tropical agricultural soil. *Journal of Science of the Total Environment* **90**. DOI: https://doi.org/10.1016/j.scitotenv.2024.176568.

Getnet, E. (2023). Adoption of Agricultural Technologies of the Barley-Based Farming System in Ethiopia. *Journal of Economic and Trade* **8**. DOI: https://doi.org/10.56557/jet/2023/v8i28642.

Gomez, K.A., and Gomez, A.A. (1984). "Statistical Procedures for Agricultural Research, 2nd edition". John Wiley and Sons, New York.

Hadis, M., Meteke, G., and Haile, W. (2018). Response of bread wheat to integrated application of vermicompost and NPK fertilizers. *African Journal of Agricultural Research* **13**,14-20. DOI: https://doi.org/10.5897/AJAR2017.12720.

Jehangir, I.A., Khan, M.H., and Bhat, Z.A. (2021). Strategies of increasing crop production and productivity in problem soils. *International Journal of Forest, Soil and Erosion* **3**,73–78. DOI: https://doi.org/10.3389/fagro.2021.680456.

Kebede, P.K., and Lele, T.T. (2022). Time of lime application on the performance of food barely in acidic soil, Gummer District, Southern Highland, Ethiopia. *Journal of Agricultural Science and Technology* **11**, 25–29.

Landon J.R. (1991). "Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics". New York.

Mulatu, B., and Grando, S. (2011). Barley research and development in Ethiopia – an overview In (miring) "Proceedings of the 2nd National Brley Research and Development Review Workshop" (B. Mulatu and S. Grando, eds.), pp 1-16, Holetta, Ethiopia. International Center for Agricultural Research in the Dry Areas.

Olsen, S.R., Cole, C.V., Watanabe, F.S., and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium carbonate. *USDA Circular* **939**, 1-19.

Panda, N. (2022). Particular issues in plant production under acid soils: The Orissa Scenario. Bhubaneswar, Orissa, IPI-OUAT-IPNI International Symposium OUAT. India.

Rajneesh, Sharma, R.P., Sankhyan, N.K., Kumar, R., and Sepehya, S. (2020). Effect of a four-decade-long application of fertilizers, farmyard manure, and lime, on forms of soil acidity and their relationship with the yield of wheat and maize in an acid Alfisol. *Journal of Plant Nutrition* **41**, 1444-1455. DOI: https://doi.org/10.1080/01904167.2018.1457684.

Sumner, M.E., and Noble, A.D. (2003). Soil acidification: The world story. *In* "Handbook of Soil Acidity" (Z. Rengel, ed.), pp 1-28. (Z. Rengel,ed.). pp. 1–28. New York, Marcel Dekker. DOI: https://doi.org/10.1201/9780203912317.ch1.

Tadese, T. (1991). Soil, plant, water, fertilizer, animal manure, and compost analysis. *Working Document* **13**. International Livestock Research Center for Africa, Addis Ababa.

Tadesse, A. (2024). Soil acidity causes in Ethiopia, consequences, and mitigation strategies. *International Journal of Agricultural and Applied Sciences* **5**, 86-100. DOI: https://doi.org/10.52804/ijaas2024.5113.

Taye, B. (2007). An overview of acid soils and their management in Ethiopia, paper presented in the third International Workshop on water management (Wterman) project, September 19-21, 2007. Haramaya, Ethiopia.

Tuneb, A., Malla, M., Sultan, M., Tesema, S., Hegano, A., and Tesema, G. (2023). Lime application for acid soil amelioration and improving the productivity of barley in Semen Ari District, Southwestern Ethiopia**.** *Ethiopian Journal of Science and Sustainable Development* **10**,100-107. DOI: https://doi.org/10.20372/ejssdastu:v10.i2.2023.719.

Woldesenbet, M., and Tana, T. (2016). Effect of farmyard manure and mineral nitrogen and phosphorus on yield, yield components, and nutrient uptake of food barley (*Hordeum vulgare* L.) varieties in Kaffa Zone, Southwestern Ethiopia. *Journal of Science and Sustainable Development* **4**, 21-39. DOI: https://doi.org/10.20372/au.jssd.4.2.2016.058.